PIONEERS OF PROGRESS

MEN OF SCIENCE

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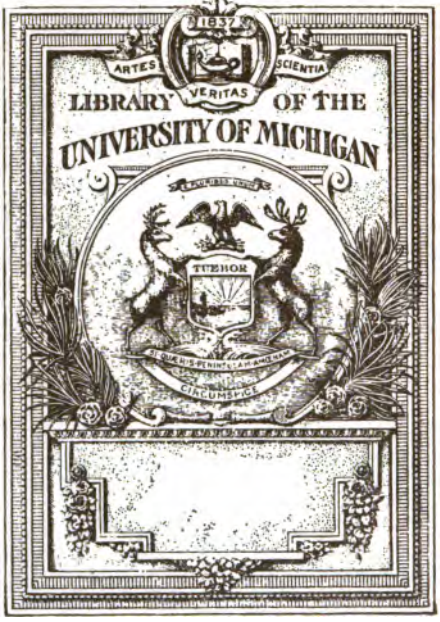

JOSEPH PRIESTLEY

FROM A DRAWING IN PASTELS BY JAMES SHARPLES IN THE NATIONAL PORTRAIT GALLERY

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JOSEPH PRIESTLEY

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CHAPTER I.

PARENTAGE—HOME LIFE—EARLY EDUCATION.

JOSEPH PRIESTLEY is probably one of the most interesting of the notable men of the eighteenth century. To his age he was perhaps most famous as a dauntless controversialist in politics and religion; he himself regarded the study of Christian Religion and Theology as his life-work, while to-day his chief title to fame rests on his scientific work.

Joseph Priestley was born at Fieldhead, a hamlet included in the parish of Birstall, which lies about six miles south-west of Leeds; the district is now closely dotted with the manufacturing towns which give the West Riding of Yorkshire its wealth and fame and unfortunately also its grime and murk. Leeds, Halifax, Wakefield, Huddersfield, Bradford, are all within a comparatively short distance of Birstall. Nevertheless in Priestley's day the district must have been a charming one; it is a gently undulating region, sufficiently far from the bleak moorlands of the Central Pennine Chain to be free from the grimness which so deeply influenced the lives and characters of the Brontë family, but yet sufficiently hilly to develop that sturdiness of character usually assumed to be lacking from the dwellers in flatter regions. Priestley was born on 13th March, 1733, the eldest child of Jonas and Mary Priestley, and was

named after his grandfather, Joseph Priestley, a maker and dresser of woollen cloth, or after his maternal grandfather, Joseph Swift, a farmer and maltster of Shafton, a village situated about six miles south-east of Wakefield. Jonas Priestley, his father, was also a weaver and dresser of cloth; this occupation was of course carried on at home according to the custom of the period, and in the district may still be seen many old houses possessing the numerous small windows necessary to give light to the looms. The Priestleys were a sturdy, long-lived stock with the evenness of temperament that comes from generations of healthy ancestors.

Priestley's mother died in 1740, soon after the birth of her youngest son. She had, in all, four sons and two daughters, and owing to the difficulty of looking after such a numerous and young family, Joseph and his brother Timothy were early committed to the care of their grandfather, Joseph Swift, with whom they remained almost uninterruptedly till their mother's death. Of his mother Priestley says: "It is but little that I can recollect of my mother. I remember, however, that she was careful to teach me the Assembly's Catechism, and to give me the best instructions the little time I was at home. Once in particular, when I was playing with a pin, she asked me where I got it; and on telling her that I found it at my uncle's who lived very near to my father, and where I had been playing with my cousins, she made me carry it back again—no doubt to impress my mind, as it could not fail to do, with a clear idea of the distinction of property and the importance of attending to it." As to his home life Priestley tells us: "My mother was a woman of exemplary piety, and my father also had a strong sense of

religion, praying with his family morning and evening, and carefully teaching his children and servants the Assembly's Catechism, which was all the system of which he had any knowledge. In the latter part of his life he became very fond of Mr. Whitfield's writings, and other works of a similar kind, having been brought up in the principles of Calvinism, and adopting them; but without ever giving much attention to matters of speculation, and entertaining no bigoted aversion to those who differed from him on the subject."

In 1742 Joseph was sent to stay with, and was apparently adopted by, his Aunt Sarah, the wife of a Mr. Keighley, "a man who had distinguished himself for his zeal for religion and for his public spirit". Shortly after this Priestley's uncle died, leaving his aunt a considerable fortune. "By this truly excellent and pious woman, who knew no other use of wealth, or of talents of any kind than to do good," Priestley was cared for as by a parent until her death in 1764. He was first sent to a school kept by a clergyman, Mr. Hague, under whose tuition he learnt Latin and Greek. In the holidays he learnt Hebrew from another minister, Mr. Kirkby, a rather formidable holiday task for a boy of twelve or thirteen to assume voluntarily. On the removal of Mr. Hague from his school Priestley went to one opened by the above Mr. Kirkby, and stayed there until it was closed. He was then about sixteen and had acquired "a pretty good knowledge of the learned languages". While at school he also learned Dr. Annet's system of shorthand and suggested to the author several improvements. This correspondence rapidly passed from the subject of shorthand to that of free will and Christianity, topics whose interest never failed for Priestley,

but whose discussion in the prefaces to his non-theological works was often as little relevant as that of King Charles' head in the memorandum of a less talented writer. Apparently about this time he contracted a severe illness due to an "ulcer on the lungs" induced by bathing in an over-heated condition; an act of imprudence which at first seems strangely out of place in the youthful apologist. The after-effects of this illness were so serious that Priestley was obliged to abandon his plan of entering the ministry, and began instead to study modern languages at home with a view to a commercial career. During this time he learnt, without a master, French, Italian and German, and apparently conducted the French and German correspondence of a merchant uncle.

Thus for two most important and formative years Priestley's education, secular and religious, was left almost entirely in his own hands; unaided he attempted to solve theological questions difficult for a mature and trained intellect. He did not waste his time; under Mr. Haggerston, a local dissenting minister and pupil of Maclaurin, he learnt geometry, algebra and other branches of mathematics; he also studied logic and natural philosophy. During the same period he taught Hebrew to Mr. Thomas, a Baptist minister, and learned Chaldee and Syriac and began to read Arabic. At this time he had a great dislike for plays and romances, so that with the exception of "Robinson Crusoe," he had read no works of this character before he went to the Academy. He says: "I well remember seeing my brother Timothy reading a book of knight-errantry, and, with great indignation, I 'snatched it out of his hands and threw it away".

Kept by his aunt to a close observance of the forms of religion, he says of this period: "By these means, not being disgusted with these strict forms of religion, as many persons of better health and spirits might have been, and on which account I am far from recommending the same strictness to others, I acquired in early life a serious turn of mind".

While still quite young he began to make notes of sermons from memory, and soon did not trouble to remember more than the headings, trusting to his own powers of composition for the amplification. To this he attributed the facility with which his works were subsequently composed. He was early thrown, at his aunt's house, into the company of unorthodox—or as he describes them—"heretical" ministers of religion. Priestley from these men imbibed a number of unorthodox religious beliefs and was therefore refused admission to membership of the Church which, with his aunt, he had always attended; this did not prevent him from remembering later, with gratitude, the benefits which he had received from that congregation. With one of the above-mentioned "heretical" ministers, Mr. Graham of Halifax, Priestley became very friendly, especially after his own entry into the Ministry; they corresponded frequently in Latin, and Priestley dedicated to him his book "Disquisitions on Matter and Spirit". During this period of physical weakness Priestley was much perturbed by religious doubts and distresses of mind, arising mainly from a confusion between theology and religion. He thus arrived at the age of eighteen "with sentiments of piety but without bigotry"—and perhaps, it may be added, without stability, a Calvinist by training but hardly by conviction.

A place was found for him in his uncle's counting-house at Lisbon, and a passage had actually been booked, when it was decided that he should resume his studies for the ministry owing to the favourable turn which his health had taken. Upon the recommendation of Mr. Kirkby, supported by his stepmother, it was decided that he should proceed to the academy of Dr. Doddridge at Daventry. This proved impossible owing to the death of Dr. Doddridge in 1751, and therefore in 1752 Priestley took up residence at the academy of Mr., afterwards Dr. Ashworth, being the first pupil to enter there. Owing to the advanced state of his education he was excused all the studies of the first year and a great part of those of the second.

Of the instruction at Daventry we have more negative than positive information. We are told by Priestley: "There was then no provision made for teaching the learned languages. We had even no compositions or orations in Latin. Our course of lectures was also defective in containing no lectures on the Scriptures, or on ecclesiastical history, and by the students in general (and Mr. Alexander and myself were no exceptions), commentators in general, and ecclesiastical history also were held in contempt."

The Mr. Alexander mentioned above was a close friend who was in the same class as, and during the first year shared the same room with Priestley. They read Greek together, but Priestley devoted more time to mathematical and philosophical studies. The students of Priestley's time were about equally divided upon all the usual questions of theological orthodoxy and heterodoxy: Dr. Ashworth, the tutor, usually took the orthodox side of the discussions and the sub-tutor, Mr. Clark,

the heterodox. As both these tutors were young the lectures often assumed the character of informal discussions.

On the whole, the period of life spent at Daventry was pleasant rather than eventful. Priestley, although argumentative and heterodox, appears to have been law-abiding, as he says: "Though Dr. Ashworth was earnestly desirous to make me as orthodox as possible, yet, as my behaviour was unexceptional, and as I generally took his part in some little things by which he often drew upon himself the ill-will of many of the students, I was upon the whole a favourite with him".

Priestley ever remained deeply attached to Daventry, his Alma Mater, in spite of its lack of tradition or splendour. Later in life he compared it favourably with the ancient Universities: "Thus while your Universities resemble pools of stagnant water, secured by dams and mounds, ours are like rivers which, taking their natural course, fertilise a whole country". The whole of his studies at Daventry were consciously directed to one end, that of fitting him for the Christian ministry. He composed there, with the aid of Mr. Clark's advice, the "Institutes of Natural and Revealed Religion". Owing to an impediment in his speech he was at times much discouraged but never for long; he consoled himself with the remembrance of St. Paul's "thorn in the flesh," and the reflection that perhaps this defect of stammering kept him from being too disputatious and thereby made him more attentive to qualifications of a superior kind.

CHAPTER II.

NEEDHAM MARKET—NANTWICH—WARRINGTON.

THE students of Daventry often amused themselves by speculations as to what the future held in store for them. Priestley never seems to have been ambitious for place, and when his tutor suggested that he should apply for a vacant ministry at Needham Market he readily consented to do so. The town was a small one in Suffolk, not far from Stowmarket and Ipswich, situated in a countryside very different in character from that to which Priestley had been accustomed. Here Priestley settled in 1755, going as assistant to Mr. Meadows, the superannuated minister, with a view to succeeding him when he died.

The congregation numbered about one hundred persons. The salary promised was £40, but from various causes it rarely amounted to as much as £30, while Priestley found that the expenses of his board alone generally exceeded £20. Under these conditions even bare subsistence would have been almost impossible but for an occasional five pounds procured for him from various religious charities. Many young men would have been embittered by these early struggles, especially men of the temperament of Priestley; for although he was humble where worldly position was concerned he possessed a clear consciousness of his own

talents, and must often have contrasted at this time his actual position with that for which he felt himself fitted. We get a hint, but only a hint, of such feelings in his remark: "Visiting that country some years afterwards, when I had raised myself to some degree of notice in the world, and being invited to preach in that very pulpit, the same people crowded to hear me, though my elocution was not much improved, and they professed to admire one of the same discourses they had formerly despised".

For the first six months the prospects of successful work seemed promising. Priestley's endeavours to implant his own pertinacious open-mindedness on religious matters in the hearts of his congregation led to his acquiring a reputation for heterodoxy which brought about an estrangement between himself and most of his neighbours. In addition to this trouble he found his monetary position much more straitened owing to the failure of his aunt's remittances. His stammering at this time increased so much as to render his preaching painful, and he applied to his aunt for twenty guineas to defray the expenses of the treatment of Dr. Angier who promised to cure all defects of speech. This led to his first visit to London.

Forced by the straitened character of his circumstances, Priestley, although extremely averse from the idea, attempted to open a school. He printed and distributed "proposals" to teach classics, mathematics, etc., but because of his heterodoxy these efforts were fruitless. He next began to lecture on science, starting with a course of twelve lectures on the use of the globes. He obtained ten hearers whose fees just more than covered the expense of the apparatus.

Further perseverance upon these lectures was rendered unnecessary by his leaving Needham Market in 1758 in order to assume the pastorate of a church at Nantwich, near Chester. The congregation to which Priestley was now attached was very different from that at Needham Market. He found at Nantwich a good-natured, friendly people with whom he lived very happily for three years. He remarks that as there were few children in the congregation there was no scope for exertion with respect to his duty as a minister; this care for the young was characteristic of him. Under these conditions he confined his ministerial visits to those houses where there were young children, and did not scruple to preach again his old sermons made at Needham, where he composed at least one every week.

If his ministerial duties were light, he assumed others which were much more onerous. He soon established a school to which he gave almost all his attention; it contained thirty boys and six girls. "Thus I was employed from seven in the morning until four in the afternoon without any interval except one hour for dinner, and I never gave a holiday on any consideration, the red letter days, as they are called, excepted." This reminds us of John Wesley's famous school where play was forbidden; it is doubtful whether the teachers or the taught would protest more loudly if such a regimen were enforced today. After closing his own school for the day, Priestley went to private teaching in the house of a rich and eminent attorney, Mr. Tomlinson. These activities naturally left him very little leisure, but he was now free from the fear of debt which had been ever with him at Needham. He was able to purchase a few books and even some scientific instruments, such as an air pump, electrical machine, etc.

His oldest scholars were taught to keep these in order and to perform small experiments with them. This appears to have been Priestley's introduction to practical, experimental science.

At Nantwich he lived with Mr. Eddowes, a member of his own congregation, who was a grocer and the most influential member of his church, and who, being himself a lover of music, persuaded Priestley to learn to play the English flute.

In spite of the great demands on his time he was able to compose, or rather re-compose, the "Observations on the Character and Reasonings of the Apostle Paul" which had already been submitted to, but not approved by, Dr. Lardner while Priestley was at Needham. He also wrote an "English Grammar" for the use of his school. This was afterwards enlarged while he was a tutor at Warrington Academy and seems to have met with some success.

In the year 1757, while Priestley was still at Needham Market, there had been instituted the "Warrington Academy for the education of young men of every religious denomination for the Christian ministry or as laymen," and Mr. Clark, of Daventry Academy, recommended his old pupil Priestley for the post of tutor in languages. However, Mr. (afterwards Dr.) Aiken was preferred. Later when the tutor of divinity, Dr. Taylor, died, he was succeeded by Mr. Aiken, and Priestley was offered the tutorship in languages. This he accepted, although it was less remunerative than his school at Nantwich and although he would have preferred to teach mathematics and natural philosophy.

The Warrington Academy was for many years one of the chief Dissenting places of education in Great Britain.

Sir T. E. Thorpe in his "Life of Joseph Priestley" describes it as "the centre of literary taste and activity, and of political liberalism of the district in which it was placed—the Areopagus of the Athens of Lancashire, as it was called". Several of its tutors were as eminent in their particular branches of knowledge as any men of their time. The poetess, Anna Laetitia Aiken, afterwards Mrs. Barbauld, was the daughter of the tutor in divinity.

Priestley soon had more leisure than at Nantwich, and congenial society enabling him to make the best use of that leisure. During the first few months he was busy preparing his courses of lectures, a labour made more arduous because at that time he had no particular liking for the subjects which he was teaching. He continued to give lectures on "The Theory of Language" and "Oratory and Criticism" as had been done by Mr. Aiken, and in connection with these introduced weekly public declamations by his pupils. Finding the curriculum designed chiefly to train the students for the generally-called learned professions, whereas in fact most of those in residence intended to take up a civil or mercantile career, Priestley introduced courses which he thought would be more suitable for such men. He therefore introduced lectures on "History and General Policy," on the "Laws and Constitutions of England," and on the "History of England". It was his intention later to publish these three courses of lectures, but the appearance of certain works by other authors rendered unnecessary, in Priestley's opinion, the publication of two of these. It is interesting to note that the book which superseded his on the "Laws and Constitutions of England" was no other than the famous "Blackstone's Comment-

aries". The "Lectures on History and General Policy" were subsequently published with a dedication to Mr. Benjamin Vaughan, who had heard them as a student at Warrington and who later emigrated to America, having previously, in 1792, sat as Member of Parliament for Calne. In the preface Priestley condemns the general ignorance of the constitution and interests of the country. After reproving the growing spirit of faction and the taste for luxury and expense, he gives vent to an appeal that might be taken word for word from some recent leading article: "Of what unspeakable advantage might be one minister of state, one military commander, or even one single member of parliament, who thoroughly understood the interests of his country and who postponed every other interest and consideration to it". Priestley, although desiring the spread of political knowledge, did not favour the idea of an educated democracy: "This is not teaching politics to low mechanics and manufacturers, or encouraging the study of it among persons with whom it could be of no service to their country and often a real detriment to themselves". Some of these opinions were afterwards modified, but throughout his life Priestley, considering his own origin, was strangely contemptuous in his references to the artisan class, their sufferings, and general mode of life.

The lectures themselves covered a very wide field; they did not last very long, as Priestley's plan was to invite relevant interruptions and a general discussion. His views on certain matters, as for instance, criminal punishment, seem to us now rather callous: "The only proper use of torture is that of punishment for atrocious crimes". For other crimes slavery is allowable as a punishment, although in a later lecture, slavery as an

institution, especially in America and the surrounding islands, is fiercely attacked. He did not apparently approve of literature merely as literature, and thought that art had reached almost the limits of its development. Especially in regard to poetry he considered that any further addition to its volume was undesirable, because much of what was added would be bad, and there was already in existence more good poetry than most people had leisure to read. Other lectures dealt with Money and Prices, National Debts, Taxes, General Economics and the Government of Colonies, with especial reference to America and Ireland. The latter problem is still unsolved, the former knot cut and not unravelled.

Besides these subjects Priestley also gave courses of lectures on elocution, logic and Hebrew. After a year or two he exchanged the latter two with Dr. Aiken for lectures on civil law, and during one year he gave a course on anatomy. The students were encouraged by Priestley to write verses in order to give them a greater facility in writing prose. He says: "I was myself far from having any pretension to the character of a poet, but in the early part of my life I was a great versifier, and this, I believe, as well as my custom of writing after preachers, as mentioned before, contributed to the ease with which I always wrote prose".

In defence of the system of studies which he introduced at Warrington, he composed an essay on "A Course of Liberal Education for Civil and Active Life," with syllabuses of the three new courses of lectures. Just at this time Dr. Brown published an educational scheme containing a recommendation for state control. Priestley therefore, on publishing his essay, added some "Remarks on his Treatise," asserting that state control

of education was "inimical to liberty and the natural rights of parents". This led him to consider the whole subject of civil and political liberty, and his thoughts were embodied in an essay on "Government," subsequently enlarged by reflections on church authority and further remarks on state education.

At Warrington he drew up a "Chart of Biography," in which the lives of eminent men were represented by lines proportional to their length of years; thus by observing the lines intersected by any particular date, the eminent men living at that time would be known, and their ages, successors and predecessors read off. As a result of this work he was awarded the title of Doctor of Laws by the University of Edinburgh. Later, at Leeds, he published a "Chart of History" on a similar plan; this is much more involved in character. It appears to have been in fairly general use and is mentioned in one of Maria Edgeworth's "Tales".

While at Warrington Priestley formed the habit of spending one month of each year in London. His son adds: "He saw and heard a great deal. He generally made additions to his library and chemical apparatus. A new turn was frequently given to his ideas. New and useful acquaintances were formed, and old ones confirmed." On the first of these visits he was introduced to several men who had a marked influence on his life: Dr. Price, Mr. Canton and Dr. Franklin. Dr. Price was then minister of Newington Green Chapel, and is famous for his work on morals and his writings on economics. John Canton, a schoolmaster, besides carrying out important physical work, also discovered the phosphorescence of calcium sulphide—the so-called "Canton's Phosphorus". The cause of this phosphorescence is

still engaging the curiosity of chemists. Benjamin Franklin, by far the best known of the three, was at this time about sixty years of age and famous as a physicist and statesman. His discoveries in electricity had been so important as to gain for him from the Royal Society—which had at first ridiculed his work—the distinction of an honorary Fellowship although he was still a British subject. At the time when Priestley met him he was occupied in fighting the battles of the American Colonies against the Home Government. His examination before a committee of Parliament made him still more well known.

Priestley has described to us how, on one day of the examination, he was enabled through the influence of Burke to be present, and has expressed his disapproval of the method of conducting the enquiry. The acquaintanceship now formed between the two men was strengthened during the next few years by their common sufferings in the cause of liberty. But the friendship produced an almost immediate and very far-reaching effect. Priestley at this time had composed all the lectures which he had to deliver, and having the necessary spare time he mentioned to Franklin a project of writing the history of discoveries in electricity, and said that he would undertake it provided that he could be furnished with the necessary books. Franklin readily agreed to provide these books, in which action he was assisted by other mutual friends of himself and Priestley, especially Mr. Michell, of Thornhill, near Leeds, the discoverer of the method of making artificial magnets. The book was published in 1767 under the title "The History and Present State of Electricity. With Original Experiments illustrated with Copperplates." It was well

received and ran through five editions in the author's lifetime. In the preface Priestley states that his idea was only to give a clear and methodical account of the present state of knowledge relating to electricity, concerning which he makes the following prophecy, rendered surprisingly true by recent research in radioactivity and electron theory: "Electricity, together with chemistry, and the doctrine of light and colour, seem to be giving us an inlet into their internal structure (*i.e.* of the various kinds of matter) on which all their sensible properties depend". His sources of information were mainly the "Transactions of the Royal Society," which at that time published abstracts of foreign papers. Having a large electrical machine of his own Priestley was led to repeat many of the experiments which he described, and also to carry out research of his own. In the course of this work he discovered, amongst other things, the conducting power of charcoal and the phenomenon of the "Alternative path," or the tendency for a high voltage discharge, such as that of a battery of Leyden jars, to take a short path of high resistance rather than a lengthy path of considerably lower resistance. His most important discovery in this connection was that of the law of force for electrostatic attraction; this law was independently rediscovered by Coulomb in 1785, eighteen years after this date, and is generally known by his name. These discoveries were remarkable in themselves but are made still more so by the circumstances in which they were effected: "These experiments occupied a great portion of my leisure time; and yet before the complete expiration of the year, in which I gave the plan of my work to Dr. Franklin, I sent him a copy of it in print. In the same year, five hours

of every day were employed in lectures, public or private, and one two-months' vacation I spent chiefly at Bristol on a visit to my father-in-law." It was not only the speed with which the work was completed that is remarkable, but also the thoroughness with which it was done. Of course it was hasty and imperfect in many particulars, but that it should have contributed so much to the real advancement of science more than compensates for its imperfections. Hasty workmanship was much more apparent in some of Priestley's later publications, and to attacks on this ground he replied: "However, whether my publications have taken up more or less time, I am confident that more would not have contributed to their perfection, in any essential particular; and about anything farther I have never been very solicitous. My object was not to acquire the character of a fine writer, but of an useful one." This excuse may be sound in particular cases, but it is extremely open to abuse. As a result of this experimental work in electricity Priestley was elected a Fellow of the Royal Society, being recommended by Dr. Franklin, Dr. Watson, Mr. Canton, and Dr. Price.

Soon after taking up his residence at Warrington Priestley decided to become ordained, apparently in order to improve his qualifications in case he should again be obliged to re-enter the ministry as a means of obtaining his livelihood. It was not the highest motive, but common enough in an age in which, for instance, nearly all teaching was in the hands of ordained ministers. In this, as in many other matters dealing with the application of spiritual principles to the conduct of life, Priestley showed an acceptance of the conventions of the day, rather out of place in one

who was, in so many other respects, a reformer and "heretic".

In 1762, shortly after his ordination, he married Mary Wilkinson, who was then about nineteen years of age. She was the daughter of Isaac Wilkinson, an iron master of Wrexham, with whose family Priestley had become acquainted through a younger son, William, who attended his school at Nantwich. The marriage was a happy one. In Priestley's words: "This proved a very suitable and happy connection, my wife being a woman of excellent understanding, much improved by reading, of great fortitude and strength of mind, and of a temper in the highest degree affectionate and generous; feeling strongly for others, and little for herself. Also, greatly excelling in everything relating to household affairs, she entirely relieved me of all concern of that kind, which allowed me to give all my time to the prosecution of my studies and other duties of my station." This last qualification was all the more important, because directly after marriage she had the responsibility of looking after two of his pupils from the academy, Benjamin Vaughan, already mentioned, and his brother William. From his wife's brothers, Priestley, later in life, received much help; the Wilkinsons were pioneers in works management and methods, and John Wilkinson ultimately built up a big industrial organisation, even coining his own monetary tokens.

With the other tutors Priestley was on very good terms; they usually met together every Saturday to drink tea and discuss the questions which interested them, questions generally relating to philosophy and religion. We get no hint that politics, national or international, formed a frequent subject for discussion,

although external events were portentous enough. They were all "zealous necessarians," determinists as we should say now, and held similar theological views.

He used occasionally to stay at Liverpool with Mr. Bentley, afterwards partner with Wedgwood of pottery fame, and an extremely able man but an unbeliever in Christianity. Priestley therefore often discussed this subject with him, and it was perhaps remembrance of some long, well-fought arguments that made him write: "We generally, and contrary to my usual custom, sat up late". He had also friends in Manchester, Bolton and other towns, but wherever he went, Priestley was not long in forming a circle of friends and acquaintances, and it is a tribute to his own character that often the friendships then made lasted long after he had left the locality.

In spite of the zealous endeavours of the tutors the Warrington Academy did not flourish at this time. There were embittered differences of opinion among the trustees which caused many supporters of the scheme to withdraw. At the same time the health of Priestley's wife began to fail, and as he had by this time an infant daughter, Sarah, to provide for, he was ready to remove to any congenial post which offered him better remuneration, his salary at Warrington being £100 per annum, and terms for boarders £15 per annum. Thus he was "most laboriously employed for nothing more than a bare subsistence".

CHAPTER III.

LEEDS—CALNE.

WHILE at Warrington, Priestley, although under no obligation to do so, continued to preach, and, as has already been mentioned, became ordained. His stammer still continued to hinder his preaching; indeed, during the first two years at Nantwich it became so bad as almost to make him abandon preaching and confine himself wholly to his school. However, by dint of practice at reading slowly and loudly he to some extent overcame this defect, but throughout his life it continued to trouble him. His preaching in spite of this seems to have been effective, for in 1767 he received an invitation to take charge of the congregation at Mill Hill Chapel, Leeds, where he was already well known; financially the change was not a great improvement, as he was to receive one hundred guineas per annum and a house. The chapel had been built in 1673, and the present building occupies the same site, in a corner of the city square in Leeds. Near to it are statues of Priestley, Watt and others. At Leeds Priestley continued for six years, on good terms with his congregation, whom he describes as "liberal, friendly and harmonious". Here he threw himself heart and soul into the work of a Christian minister; work which he considered as the most honourable of any, and in whose attendant and necessary studies he took the greatest

pleasure. This transference to Leeds was probably the cause of Priestley's henceforth devoting his main efforts to theological work. He at once resumed the studies in theology which had been interrupted by the business of teaching at Nantwich and Warrington, and it is characteristic of what he himself calls his "disposition to precipitancy" that through the perusal of one book he became shortly after his arrival at Leeds a Socinian in theology. He next began the publication of the "Theological Repository," an intermittent work to which he was the chief contributor. Three volumes were published at Leeds. For the use of his congregation he published numerous tracts.

Here at Leeds, Priestley began his career as a theological controversialist by a treatise in reply to some angry remarks on his "Discourse on the Lord's Supper". It is said that the character of a controversialist was forced upon him, but if so he showed a surprising aptitude for the part and never shrank from the combat; indeed, later, he wrote an annual "Defence of Unitarianism," until, as he somewhat ruefully remarks, it appeared to himself and his friends that his antagonists produced nothing to which it was of any consequence to reply. While at Leeds several pamphlets were also composed concerning the relations between Dissenters and the Government, and Priestley soon acquired the reputation of being one of the chief upholders of heterodox principles in religion and advanced ideas in politics. The distinction is not merely verbal, because his heterodoxy in religion has made little progress on the whole, while in politics many of his hopes have been realised. The success of John Wesley's preaching led to the composition by Priestley of several pamphlets designed to com-

bat what he considered were errors in the tenets of Methodists.

Besides these theological publications Priestley also composed several other works of a general nature, including an "Essay on Government," an "English Grammar," and a "Treatise on Perspective". This last work he wrote in consequence of the difficulties he himself had in obtaining correct rules for drawing his scientific apparatus; in it there occurs the first printed reference to the use of india-rubber as an eraser. Encouraged by the success of the "History of Electricity" he proposed to write histories of all the branches of experimental science, and next undertook and published a "History of Discoveries Relating to Vision, Light and Colours". The sale, however, was not sufficiently promising to warrant the further continuance of the plan, and Priestley's further scientific work consisted almost entirely of original experiments.

Apart from theological studies his chief occupation at Leeds was the carrying out of experiments relating to electricity and the commencement of the work on gases which ultimately gained for him the title of the "Father of Pneumatic Chemistry". At Warrington Academy he had listened to lectures on chemistry by Dr. Matthew Turner, a physician of Manchester, but he knew very little of the subject when he began his experiments. He was led to the study of "fixed air" (carbon dioxide) owing to the circumstance of the first house which he inhabited at Leeds being next to a brewery. By exposing water to the action of the gas—fixed air—given off from the fermenting wort, he succeeded in obtaining a solution. But he soon found a more effective and convenient method of obtaining this solution:

the gas was generated by the action of sulphuric acid upon chalk, passed through a bladder to allow of the deposition of moisture and then bubbled into water. He suggested that by the use of pressure the water might be more strongly impregnated with the gas. Priestley's first publication on gases appeared in 1772 and dealt with these experiments, the subject having some importance beside that of mere novelty, because it was hoped that the solution—now familiar as "soda water"—might be of use in preventing scurvy. The paper was considered by the College of Physicians and by them brought before the Lords of the Admiralty. For this work, published with additions in the "Philosophical Transactions of the Royal Society," Priestley was awarded the Copley Medal. In connection with these experiments Priestley devised the now well-known pneumatic trough, a crude form of which had been used by Hales, and a piece of apparatus so simple as almost to rank with the wheel or the lever, and like them important because commonplace. The first form used by Priestley was improvised from an earthenware trough used for washing linen. This contained water below whose surface was fitted a shelf containing funnel-shaped perforations with the narrow end upwards; the delivery tube from the apparatus generating any particular gas was placed below one of these openings and a tube or other vessel filled with water placed over it to collect the gas in the usual way.

Already he had begun to acquire a reputation outside this country, for while at Leeds he was asked by the Grand Duke of Tuscany to procure for him the best electrical machine that could be made in England. The design for this machine was drawn up by Priestley

himself, to whom was chiefly due the revival in the use of large electrical machines. Evidence of his reputation in British scientific circles was the proposal that he should accompany Captain Cook on his second voyage to the South Seas. Priestley consented to go and an assistant was appointed to take his place at Mill Hill. However, objections were raised at the last minute because of Priestley's theological views—apparently a person of no principles would have been more acceptable than one of principles opposed to those of the Board of Longitude, and the appointment was given to Dr. Forster. A far weightier objection to Priestley's appointment would have been his lack of knowledge of Natural History.

During one of his London visits he made the acquaintance of Mr. Lindsey, a friendship which, said he, "has been the source of more real satisfaction to me than any other circumstance in my whole life". Mr. Lindsey was minister of the parish of Catterick, but in 1773, owing to a change in his views, he left his church and went to London, where he afterwards began to give services in the Essex Street Chapel. Priestley and Lindsey were at one in everything that they thought to be for the interest of Christianity; and as they became more intimate, so great was Priestley's regard for the judgment of Lindsey and Mrs. Lindsey, that he published no theological work of any importance without first submitting it to them.

In 1773 Priestley left Leeds in order to take up a position with Lord Shelburne, nominally as librarian. The Earl of Shelburne, an Irish nobleman, who had had a distinguished Parliamentary career, was at this time living in comparative retirement. He afterwards re-

entered public life, as Prime Minister concluded peace with the United States of America, and subsequently became Marquis of Lansdowne. Priestley had been recommended to him by Dr. Price as a man suitable to be a literary companion. He carried out certain of the functions of a private secretary and of a librarian, but his actual position was rather indefinite. During the summer he lived with his family, now increased by two sons, at Calne, near to Bowood, the Earl of Shelburne's Wiltshire seat; the greater part of the winter was spent in London. Priestley received £250 per annum together with a house; there was also to be an allowance in case of death. In addition he received £40 per annum from Shelburne towards the expenses of his experiments on gases, etc., and £40 per annum from a group of subscribers who were sensible that many of these experiments were not carried to completion owing to lack of means. Shelburne often brought his guests, especially such as were foreigners, to witness Priestley's experiments.

In the autumn of 1774 Priestley visited the Continent as the companion of Lord Shelburne. They made the tour of Flanders and Holland, and went as far as Strasburg, returning to England via Paris where they spent a month. This first experience of foreign travel was very pleasing to Priestley; he made the acquaintance of many men eminent in politics, literature or science.

Apparently he soon wearied of Paris, for he left Lord Shelburne there and returned to England with a Mr. Magellan, a relative of the great navigator. While in Paris he met Lavoisier and other chemists, and from that circumstance arose the controversy as to the priority of the discovery of oxygen. Priestley's own words are

quite decided: "I frequently mentioned my surprise at the kind of air which I had got from this preparation (*i.e.* mercury oxide) to Mr. Lavoisier, Mr. Le Roy and several other philosophers who honoured me with their notice in that city, and who, I daresay, cannot fail to recollect the circumstance".

Priestley was not surprised to find that all the scientists to whom he was introduced in Paris were either agnostics or atheists, and adds: "As I chose on all occasions to appear as a Christian, I was told by some of them that I was the only person they had ever met with, of whose understanding they had any opinion, who professed Christianity". He soon found that their knowledge of Christianity was very superficial, and that the same was the case with a great number of the company whom he met at Lord Shelburne's. This circumstance induced him while he was with Lord Shelburne to write the first part of his "Letters to a Philosophical Unbeliever". The second part was written at Birmingham, and the third part written on the ship that was taking him to America in 1794. They are written as to an anonymous friend in an easy conversational style, and, apart from an occasional reference to Wilkes or the taxation of the American Colonies, might almost be the work of a much more modern apologist. Occasionally we light upon a compressed statement almost epigrammatic: "Something must have existed from all eternity, for otherwise nothing could have existed at all;" or as when speaking of "the causes of infidelity in persons of a speculative turn of mind," he mentions the "affectation of being wiser than the rest of mankind" so that "from a fondness for singularity he may be singularly in the wrong," a reminiscence of Lady Mary Wortley Montague's "General conclusions are generally wrong".

In spite of the large amount of time which Priestley devoted to experimental science, he yet managed to compose many theological and metaphysical works. Amongst these were: "Lectures on Oratory and Criticism," dedicated to Lord Fitzmaurice, Lord Shelburne's eldest son; the third part of the "Institutes of Natural and Revealed Religion," and three "Dissertations on the Doctrine of Association of Ideas," in the preface to which he casually suggested that possibly the mental or sentient part of man might be merely a form of activity of the material body; the immortality of man he regarded as only possessing a basis in the Christian doctrine of the resurrection. These casual remarks were much misrepresented at the time and brought upon him the reputation of an atheist and an unbeliever in revelation. This merely incited Priestley to publish his "Disquisitions on Matter and Spirit". Several of Lord Shelburne's friends unsuccessfully attempted to dissuade him from the publication of this work lest it should bring odium upon his patron.

While with Lord Shelburne, Priestley carried out a number of experiments upon gases—his discovery of oxygen was made at this time—and published four volumes of his "Experiments on Air".

Priestley's spending each winter in London led to a much closer acquaintance with Franklin; they were members of the same club and were constantly together at this time. Their conversation related chiefly to the differences with America then arising. Of Franklin Priestley writes: "I can bear witness that he was so far from promoting, as was generally supposed, that he took every method in his power to prevent a rupture between the two countries. He urged so much the

doctrine of forbearance that, for some time, he was unpopular with the Americans on that account, as too much a friend to Great Britain." Again he writes: "He dreaded the war, and often said that, if the difference should come to an open rupture it would be a war of *ten years*, and he should not live to see the end of it. In reality the war lasted nearly eight years, but he did live to see the happy termination of it. That the issue would be favourable to America he never doubted." The last day that Franklin spent in England was in the company of Priestley, reading American newspapers, chiefly for their accounts of the reception of the "Boston Port Bill". Franklin, who was an unbeliever in Christianity, acknowledged to Priestley that he had not given so much attention to the study of the evidences of Christianity as the subject required, and asked to be recommended a few treatises on the subject. They continued to correspond occasionally for many years: in 1782 he wrote from France to tell Priestley of a meeting of the Academy of Science at which the Count du Nord (afterwards Emperor of Russia) was present, and where Lavoisier succeeded in melting platinum by burning charcoal in oxygen. In 1788 Franklin, writing to M. Le Veillard, asks to be remembered to that "honest heretic" Priestley whose "honesty has brought upon him the character of heretic". Many other letters passed between them.

Priestley afterwards said of the time spent in the family of Lord Shelburne: "I can truly say that I was not at all fascinated with that mode of life. Instead of looking back upon it with regret, one of the greatest subjects of my present thankfulness is the change of that situation for the one in which I am now placed;

and yet I was far from being unhappy there, much less so than those who are born to such a state and pass all their lives in it. These are generally unhappy from the want of necessary employment."

During the last two years spent with Lord Shelburne Priestley was sensible of a strained character in their relations. He discussed this with his friends; in 1780 Franklin wrote from Passy advising him to continue with Lord Shelburne "under all the present disagreeable circumstances" until the end of the agreed term: "all human situations have their inconveniences; we *feel* those that we find in the present and we neither feel nor *see* those that exist in another". At length Lord Shelburne himself proposed that they should part, offering Priestley an establishment in Ireland. This was refused, and the terms mutually agreed upon in 1773 were carried out. Priestley received an annuity of £150 and took up his residence in London. Later in life Shelburne proposed to Priestley that he should return to his former position, but this offer was not acceptable.

CHAPTER IV.

BIRMINGHAM AND EXPERIMENTS ON AIR.

WHILE living at Calne, Priestley's expenses had increased to such an extent that in spite of his augmented salary he was barely able to provide for the removal to London. In this situation he received much help from Mrs. Rayner, one of the congregation of Mr. Lindsey, who by this time was in charge of a church in London. Priestley now proposed to set up a school and thus provide for himself, but Dr. Fothergill and others who had previously helped to provide for the expenses of his experiments now undertook to increase their allowance so that Priestley should be under no necessity to undertake teaching. This offer Priestley accepted. Amongst those who made this annual allowance was Josiah Wedgwood, the celebrated manufacturer of pottery. Many others also helped, and it was from a desire to manifest his gratitude to these and other friends and benefactors that Priestley wrote his memoirs. Wedgwood also helped him considerably by gifts of apparatus from his pottery works: glass apparatus and the large burning lenses so necessary in many of his experiments were supplied by Mr. Parker of Fleet Street.

Mr. John Lee, of Leeds, one of the congregation of Dr. Lindsey, and through him a friend of Priestley's, proposed that he should receive a pension from the Civil

List. This was declined, as were also several subsequent repetitions of the proposal.

Priestley had not decided to settle in London, and when his brother-in-law, John Wilkinson, proposed that he should come to live at Birmingham he assented and was there provided with a house. About three months after settling at Birmingham the minister of the New Meeting, Mr. Hawkes, resigned, and Priestley took his place, with Mr. Blyth as colleague. Owing to the large amount of time taken up by his scientific and theological work he confined his duties to the Sunday, leaving the work of the week days to be carried out by Mr. Blyth. He was there instrumental in opening one of the first Sunday Schools for children in the kingdom.

Shortly after his settlement at Birmingham he published his "History of the Corruptions of Christianity," an attempt to get back to the primitive basis of Christianity. It has been pointed out that his method of treatment in this and similar works marks him as "the genuine precursor of the properly historic treatment of biblical and theological questions". This work caused him to be attacked by nearly all branches of the Christian Church, and in defence of his opinions he published a "History of Early Opinions concerning Jesus Christ" and subsequently commenced a "General History of the Christian Church to the Fall of the Western Empire".

While at Birmingham he composed the first part of his Memoirs, which he concludes with some reflections of a personal nature. He was particularly thankful that he had inherited a happy temperament of mind and body. He never suffered from headaches or other complaints unfavourable to study. At all times of the day he could apply himself to mental work; it was not even necessary

for him to retire from company, but many of his writings were composed by the fireside with his wife and children round him. Nothing but uninterrupted reading or speaking disturbed him. Except for a short period while with Lord Shelburne his health had been uniformly good from the age of eighteen. His son states that he never slept more than six hours. He rose at about six and generally worked in his study until eight, when he breakfasted with his family. The morning was spent usually in his study in literary work; occasionally some time was spent in his laboratory. He dined at one, and contrary to the custom of the age rarely drank wine or beer. In the afternoon he usually took a walk; according to his son he walked very firmly and expeditiously. At eight he supped and generally spent the remaining time with his family, often in some game such as chess, backgammon or whist. Nothing ever depressed his mind for more than a short period. Frequently he observed that a few days after some troublesome event he felt much less depressed than at any other time. The anticipation of a similar reaction never failed to lessen the effect of any new cause of anxiety, and together with his belief that all things were ordered for the best gave him considerable composure of mind throughout his life. When he was a young author attacks on his writings pained him considerably, but later they produced hardly any effect. This was partially due to his resolution frankly to acknowledge any mistake into which he might realise that he had fallen: "That I have never been in the least backward to do this in matters of philosophy can never be denied".

His memory in certain respects was extremely bad, and perhaps it was this cause that rendered his theoretical deductions from his own experiments so very feeble.

He often forgot entirely the substance of his own notes or even of the works which he had published. On account of this he used a variety of mechanical expedients to secure and arrange his thoughts, especially in the composition of his longer works. With characteristic ingenuousness he remarks: "As great excellences are often balanced by great, although not apparent, defects, so great and apparent defects are often accompanied by great, though not apparent, excellences. Thus my defect in point of recollection, which may be owing to a want of sufficient coherence in the association of ideas formerly impressed, may arise from a mental constitution more favourable to new associations; so that what I have lost with respect to memory may have been compensated by what is called invention, or new and original combinations of ideas."

At Birmingham Priestley was a member of the "Lunar Society". This was an informal association of men interested in science, especially in chemistry. It derived its name from the fact that it usually met at the time of the full moon. The members dined together and then discussed some pre-arranged subject. Many of Priestley's discoveries were first announced at these meetings. Amongst its members were Dr. Withering, a physician and botanist; James Watt, the celebrated engineer, and his partner Boulton; and Dr. Erasmus Darwin, the author of "The Botanic Garden," and grandfather of the great Charles Darwin.

In the period 1780-91, Priestley carried out numerous experiments on gases and republished his "Experiments on Air" in three volumes, dedicated to the Prince Regent. Priestley's reputation as a chemist is derived chiefly from the work described in these three volumes.

The results of the investigations are throughout explained in terms of the Phlogistic Theory, to which Priestley remained a life-long adherent.

The Phlogistic Theory owed its inception to the attempt of a German physician, J. J. Becher (1635-82), to explain the phenomena attending combustion and the calcination of metals in air. The changes attending these two processes had been regarded throughout the middle ages as due to similar causes, and Becher explained them by assuming the decomposition of the combustible substance or metal into a principle of combustibility—called "terra pinguis"—and a residue.

Becher's hypothesis was extended by Stahl (1660-1734), who suggested that when a metal, such as iron, was heated in air it lost a volatile constituent, called by him "phlogiston"; the residue, now known to be the oxide of the metal, was described as the "calx" from the Latin word for ashes. The escaping phlogiston was assumed to be absorbed or taken up by the air in a manner somewhat resembling that in which a sponge takes up water; the mechanism of this side of the process was never clearly apprehended and described. A similar explanation was applied to the process of combustion of such substances as sulphur, charcoal, etc.

It followed from this hypothesis that substances burnt more readily according as they were richer in phlogiston and according as the gas in which they were heated was less saturated with phlogiston. The theory thus clearly recognised the dependence of combustion upon the nature of the surrounding gas, and it was also recognised that a given volume of air had only a limited power of supporting combustion. A gas which

could no longer support combustion was regarded as having absorbed, or as containing its full amount of phlogiston and was described as "phlogisticated". If on the other hand a gas previously incapable of supporting combustion, or capable of doing so only to a limited extent, were transformed to one well able to support combustion, then it was regarded as having become "dephlogisticated"; some phlogiston had been removed, and so, like a wrung-out sponge, it could reabsorb more.

The mistake of assuming that combustion or ignition in air always resulted in the evolution of a volatile constituent was perhaps a natural one when only the visible phenomena attending combustion were considered. The Phlogiston Theory received further support from the fact that on heating the calx of a metal with charcoal or sulphur the metal could be regenerated; the obvious explanation of this would be that the charcoal gave up something to the "metallic calx". Charcoal was itself readily combustible, *i.e.* rich in phlogiston, and therefore its function was to replace the phlogiston lost by the metal during calcination. Becher discovered that a similar process regenerated sulphur from sulphuric acid, and thus the Phlogiston Theory grouped together and explained the calcination of metals in air, the burning of such substances as sulphur to form acids—although the products of combustion in the two cases differ very widely in character—and the regeneration of the original substance by the action of charcoal.

The Phlogiston Theory was also used to explain the differences between the solution of metals and their calces (oxides) in acids. The metal dissolved with the evolution of a combustible gas, the calx without such action. The calx was produced, however, from

the metal by the loss of phlogiston, the combustible principle, so that the solution of the metal was regarded as taking place in two stages: (1) The loss of phlogiston to form the calx, and (2) the solution of the calx in the acid, as if the substance to be dissolved had originally been a calx; the liberated phlogiston, either by itself or united with a constituent of the acid, escaped as a gas, which was naturally combustible as it contained the phlogiston of the metal.

The weakness of the Phlogistic Theory was phlogiston. The nature of this substance or principle was never clearly defined; sometimes it was a "principle," sometimes a substance; for a time it was identified with hydrogen. It was very difficult to explain, from the point of view of the Phlogistic Theory, the increase in weight that took place on the calcination of metals. Many of the chief facts which contributed to its overthrow were supplied by the researches of Priestley himself. Nevertheless, the Phlogistic Theory had itself prepared the ground for the Oxygen Theory; like the latter theory it correlated the phenomena of combustion, calcination and respiration, and explained the process of reduction. Wherever the Phlogistic Theory refers to "loss of phlogiston," the modern view is arrived at by substituting the words "addition or absorption of oxygen"; and vice versa. The correlation of combustion, respiration, etc., remains as the lasting contribution of the Phlogistic Theory to chemical science.

The Phlogistic Theory was not the only faulty weapon in the armoury of the chemists of Priestley's age. There was considerable vagueness in the ideas with respect to elements and compounds. The doctrine of the four elements, earth, air, fire, and water, still lingered in the

minds of many teachers. Especially in regard to gases there was a distinct unreadiness to regard various gaseous substances as other than modifications of some primordial gas, the modified properties being regarded as due to admixed substances, just as water may be clear and sparkling or stagnant and fetid and still remain water. Quantitative work was very rarely carried out, and when attempted often gave erroneous results either from faulty manipulation or imperfect knowledge. Priestley's neglect of the quantitative side of chemistry led to his making many mistakes and missing many discoveries. This neglect was due, it would almost appear, to a complete lack of appreciation of the value of quantitative data. The state of mind is not so strange as would at first appear, seeing that, at the period in question, quantitative analysis was still in its infancy. Moreover, Priestley was not only an experimental but also a speculative philosopher and a theologian. His studies in other directions than experimental science would not be such as to lead him to attach weight to quantitative data.

In the original six volumes of the "Experiments on Air" Priestley had arranged his work to a large extent in chronological order, a method necessitated by the fact that each volume was generally published as soon as sufficient results had accumulated. In revising this work and republishing it in three volumes, Priestley rearranged it so that the chronological order was no longer followed, but the data were classified according to subjects.

After a preface containing the usual references to theology and ethics Priestley described his experiments with fixed air (carbon dioxide). He found that the gas prepared by heating powdered limestone in a gun barrel

always contained a large proportion of "inflammable air," which he ascribed to the action of the iron. His "inflammable air" was in fact carbon monoxide, a gas which he several times isolated but never troubled to characterise; its actual "discovery" was left to Cruikshank. He was then led to examine the effect of heat upon a number of substances, generally enclosing them in a gun barrel for the purpose and collecting the issuing gas over water. Similar experiments had already been carried out by Hales. In this way by heating coal he obtained a gas of which he states that the first portions burnt with a white lambent flame and the last with a blue one. In this experiment he approximated very closely to the actual conditions used for manufacturing coal gas at a much later date.

He tried numerous methods of making carbon dioxide, such as the action of nitric acid upon charcoal or ethyl alcohol, the action of charcoal on mercury oxide, etc. Some of his methods of preparation seem somewhat doubtful; thus he says that iron and mercury oxide yield carbon dioxide, as do also phosphorus and oxygen, mercury and nitric acid, etc. Many of these results are doubtless due to the lack of care exercised over his experiments. We know that the water in his pneumatic trough was often unchanged for months, and the gases collected would include carbon dioxide, carbon monoxide, impure hydrogen, etc. It is not to be wondered at that under such conditions carbon dioxide was formed in most of the reactions carried out. By passing the electric spark in carbon dioxide he obtained carbon, "inflammable air" (carbon monoxide) and "dephlogisticated air" (oxygen). The "inflammable air" he confused with hydrogen. By heating iron in carbon dioxide by the sun's rays he

obtained an inflammable gas, probably carbon monoxide again.

His experiments on "inflammable air" are full of useful information; thus by sparking the vapours of certain oils he prepared hydrogen, a method which is now technically employed for the manufacture of this gas. By passing the spark between mercury surfaces he proved that the effect was due entirely to the spark and not to the iron wire used as leads. He also decomposed ammonia gas to hydrogen and nitrogen. In connection with these experiments he notes a fact, not then long discovered, that charcoal is capable of absorbing large volumes of gases and expelling them on heating. His experiments on "inflammable air" are to some extent spoilt by his lack of differentiation between various inflammable gases; thus under the term "inflammable air" he groups gases as widely different as hydrogen, hydrogen sulphide, carbon monoxide, methane, phosphoretted hydrogen and coal gas.

In the course of his investigations on "inflammable air," Priestley proved by a series of well-executed experiments that water was essential to the production of hydrogen from iron. From these results Cavendish concluded that water was an essential constituent of "inflammable air," a conclusion to which Priestley assented. Speculations as to the composition of water itself were at this time occupying the minds of many chemists both in Great Britain and on the Continent. Watt, the engineer, made the suggestion, stated thus in a letter of Priestley's: "Mr. Watt concluded from some experiments of which I gave an account to the Royal Society, and also from some observations of his own, that water consists of dephlogisticated and inflam-

mable air, in which Mr. Cavendish and M. Lavoisier concur with him". The experiments of Priestley's referred to above were those, subsequently proved to be incorrectly interpreted, on the "conversion of water to air".

It is obvious that Priestley's view of the composition of "inflammable air" was incompatible with Watt's view of the composition of water, and many experiments were carried out by Priestley in order to throw light upon the two interrelated questions. By passing steam over heated iron he produced "inflammable air" (hydrogen) and "iron calx" (iron oxide). This "inflammable air" when heated with "iron calx" regenerated iron and water. "Iron calx" was also produced when iron was heated in air or "dephlogisticated air" and was therefore produced from iron by loss of phlogiston. In similar supposed accordance with this view was the fact that by heating "iron calx" with charcoal—a substance rich in "phlogiston"—iron was regenerated.

The production of "inflammable air" from steam and iron was then explained by Priestley on the assumption that the phlogiston given up by the iron combined with some of the steam, and that this compound of phlogiston and water constituted "inflammable air" or hydrogen. On passing this gas over "iron calx" it naturally restored phlogiston to the calx and regenerated iron, while at the same time the water previously combined with the phlogiston was liberated.

Priestley found, however, that charcoal and "iron calx" gave "inflammable air"; this gas was really carbon monoxide, but Priestley—on very little evidence beyond the inflammability—assumed that the gas was identical with that from iron and acids, etc., *i.e.* hydrogen, and

was therefore a compound of phlogiston and water. The phlogiston necessary for its production by the method indicated above would come from the charcoal, but the water must have come from the "iron calx" which was thus, according to Priestley, iron less its phlogiston and combined with water.

This left Priestley with the difficulty of explaining why "iron calx," which contained water, could be prepared as well by the action of air or "dephlogisticated air" as by steam. The explanation adopted was that "dephlogisticated air" contained water and that this water accounted for its action upon iron. He showed further that steam passed over charcoal produced "inflammable air"; this was really a mixture of hydrogen and carbon monoxide, and the process now serves for the commercial production of "Mond gas," used to-day in enormous quantities. But Priestley's conclusion was that the charcoal served to restore phlogiston to the water, and therefore the "inflammable air" produced was a compound of phlogiston and water, thus confirming previous results.

At the suggestion of Cavendish, he examined the effect of copper upon nitric acid, and succeeded in preparing and identifying nitric oxide or "nitrous air". Hales had already prepared this gas and showed that when mixed with common air, it produced a reddish-brown gas soluble in water; to Priestley is due the credit of showing that this property of "nitrous air" may be made the basis of a method for the quantitative analysis of the atmosphere. He showed that common air was diminished by about one fifth of its volume when it was mixed with "nitrous air," and exposed to the action of water. Cavendish obtained more accurate

but only slightly different results by the use of the same method.

According to Priestley, ordinary air and "nitrous air" reacted in such a way that phlogiston was liberated from the latter which was then converted back to nitric acid or "spirits of nitre". Later he assented to the view of Dr. Metherie that "nitrous air" did not give up phlogiston to become nitric acid, but that the latter consisted of "nitrous air" united with "dephlogisticated air". In connection with these experiments he suggested that nitric oxide was more soluble in water when mixed with nitrogen peroxide than when not so mixed. These experiments led also to a study of the properties of nitrogen peroxide. He showed that on heating this gas it became darker in colour. By the action of "nitrous air" upon olive oil, he produced a solid, probably the stereoisomer whose existence was afterwards explained by the van 't Hoff theory of spatial configuration. The effect on turpentine and other oils was also examined. He further found that nitrogen peroxide was soluble in a solution of ferrous sulphate and produced a characteristic deep brown coloration. He tested the antiseptic power of nitric oxide by preserving pigeons in it; one which had been thus preserved from 28th April until 4th June was then cooked, and had a peculiar but not offensive taste!

It was found that nitric oxide exposed to the action of iron or "liver of sulphur" was diminished in volume, but the gas so produced was not examined until some two months after it was generated, a delay not uncommon in Priestley's laboratory. This new gas was found to possess several surprising properties; thus although nitric oxide did not support combustion this

new gas was a better supporter of combustion than air itself although produced by a reaction which when applied to air deprived it of the power of supporting combustion. The new gas was called "Dephlogisticated Nitrous Air" because it supported combustion, but by its method of preparation it should have been "phlogisticated". Priestley showed that when this gas was heated it increased in volume and became decomposed into "phlogisticated air" (nitrogen) and "dephlogisticated air" (oxygen).

As early as 1771 he had heated nitre in a gun-barrel and obtained a gas with a very enhanced power of supporting combustion. Of the actual discovery of oxygen in 1774, he writes: "The contents of this section will furnish a very striking illustration of the truth of a remark which I have more than once made in the course of my philosophical writings and which can hardly be too often repeated, as it tends greatly to encourage philosophical investigations: *viz.* that more is owing to what we call chance, that is philosophically speaking, to the observation of events arising from unknown causes, than to any proper design or preconceived theory in the business". Happening to possess a "burning lens of considerable force" (it had a diameter of twelve and a focal length of twenty inches), he tried the effect of heat on numerous substances. Hales and Boyle had used the same method of heating substances; Boyle, by thus heating red lead contained in sealed glass tubes, had actually burst the tubes by the pressure of the evolved gas. Priestley used "mercurius calcinatus per se" (mercuric oxide), and on 1st August, 1774, prepared oxygen by heating this oxide over mercury. He collected the evolved gas and showed that it possessed a remarkable

power of supporting combustion, similar to that possessed by nitrous oxide.

Further work on this gas was abandoned for some months, during which time Priestley visited Paris where he mentioned his discovery to M. Lavoisier and others; during the same period he was also engaged in the investigation of sulphur dioxide, which he had not long discovered.

On returning to the work on oxygen a chance experiment led him to recognise its peculiar power of supporting combustion; his own words are: "I cannot at this distance of time recollect what it was that I had in view in making this experiment, but I know I had no expectation of the real issue of it. Having acquired a considerable degree of readiness in making experiments of this kind, a very slight and evanescent motive would be sufficient to induce me to do it. If, however, I had not happened, for some other purpose, to have had a lighted candle before me, I should probably never have made the trial; and the whole train of my future experiments relating to this kind of air might have been prevented." The experiment referred to above is that in which Priestley found that the residue left after treating this new gas with a certain volume of nitric oxide was still capable of supporting combustion. He had already shown that ordinary air acted upon by a sufficient volume of nitric oxide left a residue quite incapable of supporting combustion. This new gas appeared to leave no such residue. He showed that the gas was eminently fitted for respiration by testing it first on mice and then on himself, and suggested that it might thus be useful in some cases of illness or to increase the rate of combustion of charcoal so as to melt platinum, and to augment the

force of explosives. He rightly concluded that his new gas was the constituent which gave to ordinary air its power of supporting combustion, etc., but was misled by his phlogistic prejudices as to the composition of this gas and therefore of common air. He showed that this new gas would be produced by a variety of reactions, some of which, such as the action of heat upon calcium acetate, are rather doubtful sources of oxygen.

Having shown that air owed its power of supporting combustion and respiration to the presence of oxygen, he concluded that most agents which impaired the quality of atmospheric air did so because they absorbed some of the oxygen. However, Priestley himself showed that air from different sources when analysed by means of nitric oxide showed no appreciable differences in the quantity of oxygen contained.

He investigated the effect of fresh paint from this point of view and showed that it absorbed oxygen. Further work showed that turpentine alone when exposed to air absorbed it; part of this absorbed air was simply dissolved and was expelled under reduced pressure.

By heating metals such as iron, tin, lead in air, he succeeded in absorbing part and leaving a residue of "phlogisticated air" (nitrogen), but failed to recognise the character of the residue and so missed the discovery of nitrogen.

He was forced to collect certain gases over mercury because of their solubility in water, and this improvement in manipulation enabled him to make several discoveries: "marine acid air" (hydrochloric acid gas), "vitriolic acid air" (sulphur dioxide), "alkaline air" (ammonia), and "fluor acid air" (silicon fluoride).

The discovery of hydrochloric acid gas was due to a

suggestion in a paper by Cavendish. Priestley produced it first by heating copper with hydrochloric acid, later he found that hydrochloric acid alone yielded this gas, and was then naturally led to prepare it by the action of sulphuric acid upon salt. The new gas was found to be extremely soluble in water and the solution then possessed all the ordinary properties of hydrochloric acid. This led to the assumption that perhaps all acids were solutions of a corresponding gas in water and so to the discovery of sulphur dioxide. He tried the action of iron filings upon this "marine acid air," and found that it gave one half its volume of "inflammable air". Chalk was found to yield "fixed air".

A similar attempt to prepare a gas by heating sulphuric acid was unsuccessful, but some of the mercury in the trough sucked back into the hot acid and there reacted with explosive violence, producing clouds of a very pungent smelling gas. This accident led to the discovery of sulphur dioxide, which Priestley imagined bore the same relation to sulphuric acid as hydrochloric acid gas did to hydrochloric acid. He showed that the gas was also formed when sulphuric acid was heated with olive oil or charcoal. He examined many of the properties of sulphur dioxide, its power of liquefying camphor and of forming with water a solution which on freezing did not evolve its gas, as did a solution of carbon dioxide, but formed an "ice" which sank.

His discovery of silicon fluoride arose from an attempt to repeat a preparation described by Scheele. Priestley showed that his new gas was decomposed by water yielding an acid solution and a stony film. Its production was due to the presence of silica in the calcium fluoride used.

By heating a solution of ammonia and collecting the gas over mercury, he next discovered "alkaline air" (ammonia), and showed that it could readily be prepared from sal ammoniac and slaked lime. The properties of ammonia were investigated, especially its reactions with the various other gases which he had discovered. With hydrochloric acid gas, he half expected to get common air, but recognised the product as sal ammoniac. He showed that carbon dioxide united with this gas to produce a crystalline, powdery solid. The majority of these ammonium compounds were found to be volatile, but the gas united with sulphuric acid to produce a non-volatile salt. He next examined the effect of the electric spark on ammonia, and showed that its effect was due to the heat and not to the light of the spark, as by concentrating the sun's rays upon pieces of earthenware, etc., inside a vessel containing ammonia gas, he succeeded in bringing about a similar decomposition to that produced by the electric spark. A similar effect was produced by passing the gas through red-hot tubes. He showed that one of the products of decomposition was "inflammable air". He observes naïvely: "I by no means conclude that I have discovered all the kinds of air that may exist in nature".

Another accidental discovery which he made was that of "chamber crystals," or nitro-sulphuric acid. This compound was first observed in some sulphuric acid which had been impregnated with oxides of nitrogen and left by chance for about six months.

He spent a great deal of time on the supposed conversion of water to "air," but himself proved that the air had diffused through the retort. He showed that the gas to which the water was "converted" depended

upon the gas surrounding the retort. The experiments by which he proved this were extremely well devised and thoroughly conclusive. He was at times surprisingly inaccurate in measurement; thus for the expansion of various gases by heat he obtained some extraordinary results, and quite missed the discovery of the law afterwards recognised by Charles and Gay Lussac.

By acting upon lead oxide with "phosphoric acid" he produced a substance which when heated yielded an inflammable gas. This was probably phosphuretted hydrogen, but Priestley apparently failed to distinguish it from hydrogen and so missed the discovery.

He found that the intensity of sound in various gases depended entirely on the density of the gas and not on its chemical properties.

One of the most important series of his experiments was devoted to the examination of the effect of vegetation upon air. He had previously been somewhat surprised to find that a growing plant did not vitiate the surrounding air, but that a candle would burn very well in air in which plants had grown a long time: "Having had some reason to think, that there was something attending vegetation which restored air which had been injured by respiration, I thought it possible that the same process might also restore the air that had been injured by the burning of candles. Accordingly on the 17th of August, 1771, I put a sprig of mint into a quantity of air, in which a wax candle had burned out, and found that, on the 27th of the same month, another candle burned perfectly well in it. This experiment I repeated without the least variation in the event, not less than eight or ten times in the remainder of the summer." He then showed that air which he had himself breathed

until it would no longer support combustion would do so after being exposed to the action of plants. He found that light was necessary for this effect and also for the development of the green colour in certain algæ. His experiments were important for their demonstration that the action of animals and plants upon air was not the same but opposed, or rather complementary. This was in direct opposition to the general opinion of his day; even Scheele maintained that air was affected in the same way by vegetation as by the respiration of animals. Priestley not only showed that a growing plant restored vitiated air but succeeded in collecting "dephlogisticated air" (oxygen) from certain algal water-plants in sunlight and from the roots of ordinary plants. Some of his neatest and most conclusive experiments were carried out in connection with this work, which throughout exhibits him as an experimenter of a very high order. Just as much of the success of Emil Fischer in elucidating the constitution of the sugars depended on his use of phenylhydrazine, so much of the success of Priestley's work on the respiration of plants was made possible by his use of nitric oxide as a reagent for detecting oxygen.

The final conclusion may be stated in his own words: "That plants are capable of perfectly restoring air injured by respiration, may, I think, be inferred with certainty by the perfect restoration by this means, of air which had passed through my lungs, so that a candle would burn in it again, though it had extinguished flame before, and a part of the same original quantity of air still continued to do so".

He carried out a number of experiments on the effect of oxygen, carbon monoxide, hydrogen, etc., upon blood,

but these produced no very great advance on earlier work. In connection with them he made some early measurements of the oxygen absorbed and carbon dioxide evolved during respiration.

His method of generating pure hydrogen by the solution of iron in dilute acid was adversely criticised, and so he carried out some experiments on the subject. He found that on solution of the iron a residue was left which gave "fixed air" (carbon dioxide) on combustion. This residue was least in quantity from malleable iron; cast iron and steel were variable in their results. He also found that occasionally the "inflammable air" (hydrogen) generated from iron yielded carbon dioxide on combustion. All this is interesting in view of the modern work on the constitution of steel, wrought iron, etc.

In spite of the excellence of his experimental work and his success in discovering so many gases, his speculations as to their composition were usually extremely unsound; thus water was regarded as the probable basis of all gases. Although he still remained an adherent of the Phlogistic Theory, his views became very modified; of the process of reduction he remarks: "The calx must part with the air as well as imbibe phlogiston in order to become a metal". Thus he recognised that "air" was taken up by a metal during calcination.

He would not admit that water consisted of hydrogen and oxygen, although by the reduction of mercury oxide in hydrogen he had himself produced water: "It must be acknowledged that substances possessed of very different properties, may, as I have said, be composed by the same elements in different proportions, and different modes of combination. It cannot therefore be said to be

absolutely impossible that water may be composed of these two elements or of any other; but then the supposition should not be admitted without proof; and if a former theory will sufficiently account for all the facts, there is no occasion to have recourse to a new one, attended with no peculiar advantage." He was the first chemist to isolate and characterise as chemical individuals a number of gaseous substances without regarding them all as mere modifications of one primordial "air". It was this lack of characterisation that prevented Hales, Priestley's predecessor, from anticipating many of these discoveries.

Priestley was usually a very bad theorist. He despised theories and hypotheses, they were to him mere opinions, to be repudiated without compunction, mere nine-pins put up to be knocked down. He rarely evolved a theory to correlate his results or worked in order to corroborate one. This was partly due to his lack of accurate quantitative data and partly to his method of working. Chemistry was really little more than a hobby to him, theology was his life-work. His chemical work was a series of experiments whose charm for him consisted in the actual manipulation and not so much in the scientific results achieved. A pretty experiment was often repeated many times, while an important discovery, such as that of oxygen, would be neglected for months. A bottle was sometimes left unlabelled and the nature of the contents forgotten; a change in volume would often be noted as "considerable" and not measured. All this merely means that Priestley was Priestley and not Cavendish; he was a brilliant experimenter but poor at quantitative work or theoretical

speculation. Of his own hypotheses, he remarks: "The sketch that I shall now give may at least serve, like former theories, to amuse us when we look back upon it after having gained a more perfect knowledge of the subject."

CHAPTER V.

"BIRMINGHAM RIOTS"—EMIGRATION—DEATH.

IN 1791 Priestley was forced to leave Birmingham owing to an outbreak of disorder known as the "Birmingham Riots". For many years he had been regarded as the protagonist of English Nonconformity and political Liberalism in an age in which the name Nonconformist represented a legal fact, and in which political freedom was regarded as having for its ultimate end the overthrow of the State. He had had theological controversies with most of the leading divines of his age of all schools of thought. At Birmingham he participated in the demand for the repeal of the Test Act, and he had previously made himself obnoxious to the Court by a pamphlet in support of Wilkes as well as by other publications.

When the French Revolution broke out he sympathised with it, and was to have been present at a dinner given on 14th July, 1791, to celebrate the anniversary of the taking of the Bastille. For some days previous to this meeting rumours of intended violence had been rife, and it was almost decided to postpone it. Instigated, it was believed, by some of the leading citizens of the town, a large crowd assembled outside the hotel where the dinner was held, and after breaking the windows there, marched off to Priestley's church, the New Meeting, and sacked

and burnt it. They next went to the Old Meeting and burnt that.

Some friends had by this time become aware of the danger to Priestley, and with his wife he was hurried off to the house of Mr. Rylands. This removal had only been effected a few hours, and William Priestley was still removing some valuable papers from his father's house, when the mob arrived and sacked it. On Friday, 15th July, they sacked three other houses, residences of those supposed to possess similar opinions to Priestley. On Saturday no less than nine houses were sacked, most of them being burnt; two of the houses attacked were the residences of ministers. On Sunday the attack on local churches was resumed, perhaps in deference to the day. The Meeting House at Kingswood, seven miles away, was burned, together with several other buildings. The riots came to an end with an attack on Edgbaston Hall which was interrupted by the arrival of the military.

Throughout the disturbances the rallying cry of the mob had been: "Church and King". King George III. made no secret of his satisfaction at the suffering inflicted on Priestley because of his opinions. There may be some faint respect for the demagogue who incites a mob to violence and then unflinchingly leads them in the attack, but one can feel nothing but contempt for the cowardly authors of this outrage upon Priestley. Not one of them was punished for inciting the rioters, but two of the mob were subsequently hanged for their share in the disturbances. The whole series of events was thoroughly wretched.

Priestley was hurried to London by friends, and there stayed for some time with Mr. William Vaughan. He

was advised to fly from the country but refused, and, on the contrary, as soon as he arrived in London made his arrival known to the Ministry and appealed for justice and indemnification. He claimed damages to the amount of £3628 and was awarded £2502 by the Court. He received a great deal of help from his brothers-in-law and friends, especially from Wedgwood.

Soon after his arrival in London he was invited to succeed Dr. Price at Hackney; this invitation he accepted, and hoped that he would be able to settle in London. But public opinion was by this time too much inflamed to allow Priestley any respite from persecution. Threats of violence were openly made; he had difficulty even in finding a house in which to live, as owners of houses were afraid lest such a tenant might bring destruction upon their property; servants would not take service with him for fear lest they should be involved in his destruction. He was shunned by his old associates of the Royal Society.

Before condemning those who treated him thus, we must remember the circumstances of the time. He held opinions similar to those held by the French at the commencement of their revolution. They had gone from liberty to licence, from freedom to lawlessness, and many in England who had sympathised with their preliminary struggles had been alienated by their subsequent excesses. Priestley had not been one of these; he had maintained, rightly we may now judge, that licence is not the fruit borne of liberty, that the blood-red blossom of lawlessness is the flower not of the seed of freedom but of repression. The feelings of his opponents were too inflamed to allow them to estimate

the force of this argument, and Priestley, one of the least violent of men, was regarded as a supporter of any extreme of violence. His position was not helped by the receipt of several sympathetic addresses from France, and even invitations to a seat in the National Convention.

He bore all these trials with a nobility and courage worthy of the highest praise. No excess either of temper or timidity marked his actions, not even while he listened to the blows with which the mob were demolishing his house. But it was borne in upon him that no useful work could now be accomplished by him in England. His sons had left the country because in it there was no prospect of their obtaining a livelihood, and had sailed to America. He had tried to take up his old theological and scientific work and composed several publications. But it is pleasant to remember a mark of appreciation shown him at one of the older Universities during this time when he was an object of popular execration; on 19th December, 1793, he preached the sermon at the service for the commemoration of benefactors at Trinity College, Cambridge. But his mind was soon made up to leave the country, and on 8th April, 1794, he sailed for New York. Thence he proceeded to Philadelphia and so on to Northumberland, Pennsylvania, where it was proposed to found a settlement mainly composed of Englishmen who had left their native land because of the recent disturbances. This scheme was abandoned, but, attracted by the beauty of the surrounding country, Priestley determined to settle there, and built himself a house on a hill-side overlooking the Susquehanna valley.

Soon after his arrival in America, he was offered the professorship of chemistry in the University of Philadelphia, but this he refused. Later in 1803 he was offered the position of principal of the college, but owing to his advanced age and other reasons he declined the proposal.

In America he resumed the work which for the previous few years had been so much interrupted. Nothing of great scientific importance was discovered by him after leaving England; he published some papers on Volta's pile, the analysis of atmospheric air, etc., and also a defence of the Phlogistic Theory. In addition he composed several theological works. He never became a naturalised American, although at one time there was a danger of his being expelled from the country as an alien. He was at too advanced an age to bear with complete equanimity the break with all his English associations, and in spite of an outward appearance of settled calm it is doubtful whether he ever regarded himself as other than a stranger in a strange land.

During the winter of 1803 his health began to fail rapidly; he experienced great difficulty in swallowing even liquid food—solid food he could not attempt to take. Nevertheless he continued to work as well as he was able. Occasionally he was unable to speak for several hours. He was busy at this time completing the printing of a theological work, and whenever his strength allowed it would read over the proofs. The work was safely seen through the press and the publication of several pamphlets proceeded with. On Monday, 6th February, 1804, he dictated from his bed several alterations in the proofs, and concluded: "That is right,

I have now done". About half an hour afterwards he died.

"Return unto thy rest, O my soul, for the Lord hath dealt bountifully with thee. I will lay me down in peace and sleep till I awake in the morning of the resurrection." (*Priestley's Epitaph.*)

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JOSEPH PRIESTLEY.

March 1733	Born.
1752	Enters as student at Daventry Academy.
1755	Leaves Daventry and becomes minister to Independent Church, Needham Market.
1762	Marries Mary Wilkinson.
1766	Elected Fellow of the Royal Society.
1767	Leeds, minister of Mill Hill Chapel.
1771	Starts his work on the effect of vegetation upon air.
1772	Publishes pamphlet on soda water; his first publication dealing with chemistry. Discovers nitrous oxide, hydrochloric acid gas, nitric oxide.
1773	Becomes literary companion to Lord Shelburne.
1774	Discovers oxygen, ammonia gas, sulphur dioxide.
1775	Publishes first volume of "Experiments on Air". Discovers silicon fluoride.
1778	Discovers nitrosulphuric acid, "chamber crystals".
1779	Leaves Lord Shelburne.
1780	Becomes minister at Birmingham.
1791	Birmingham Riots; house wrecked; Priestley goes to London.
1794	Sails for America.
1804	Death.

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